Dynamic Balancing Experiment

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كلية الهندسة الميكانيكية

المرحلة الثالثة

DYNAMIC BALANCING EXPEREMENT

INTRODUCTION

Balancing is the technique of correcting or eliminating inertia forces; such forces cause unbalancing which sometimes may reach dangerous amplitudes and frequencies. Even if not dangerous, may increase the material stresses and subject bearing to repeated loads which case parts to fail by fatigue.

OBJECT

To verify experimentally the principle of dynamic balancing of rotating masses on a high speed driven shaft.

APPARTUS

The apparatus consist of a frame which a shaft-carrying base the driving motor is suspended by three chains, the suspended set should be horizontal that
may be chained by adjusting the leveling screws fitted at the base of the apparatus. There are five attached disks on which rotating masses may be attached from a certain locations from the center of rotation these disks can be fixed at different locations along the shaft which may be measured by the scale, the rotating masses angular position can be known from the angular divisions on the rim of the disc.

BACKGROUND THEOREM

Static and dynamic balance:

When shaft is carrying several eccentric masses is in *static* balance, the center of gravity of the system lies in the axis of the shaft so that the shaft and attached masses remain in any position in which it is placed. When the shaft rotates, however, centrifugal forces act upon the masses, and if these are not rotating in the same plane,' couples also act upon the shaft. Therefore* for complete *dynamic* balance,

(i) the resultant force acting upon the shaft must be zero, and
(ii) the resultant couple acting upon the shaft must be zero.

Balancing of masses rotating in the same plane:

If m1 m2, m3, etc., (Fig. 1) are the out-of-balance masses and

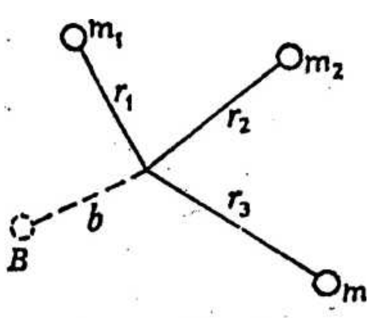


Fig. 1

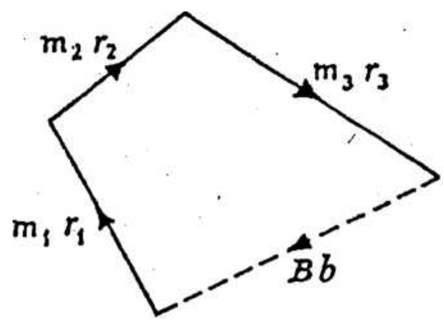


Fig. 2

r_1 r_2, r_3, etc., are the respective radii of rotation, then for dynamic balance, the vector sum for the centrifugal forces must be zero,
i.e. $\sum m\omega^2 r = 0$, where ω is the angular speed of the shaft.
i.e. $\sum m.r = 0$, since ω^2 is the same for each mass.

If, therefore, a force polygon with sides representing the magnitudes and directions of the mass-arm products m/r/, m_2r_2, etc., is drawn, Fig.2, the closing side represents the product of the balance mass, *B,* and radius of rotation, *b.*

The condition $\sum mr = 0$ is also the condition for static balance.

Balancing of masses rotating in different planes (Dalby's Method):

If the out-of-balance masses m_1 m_2, m_3, etc., Fig. 3 are situated at distances l_1 l_2, l_3, etc., from reference plane, the forces m_1r_1, m_2r_2, etc., may be transferred to the reference plane by the addition of couple of magnitude $m_2r_2l_2$, etc., acting in the planes containing the respective forces and the shaft axis. Then, for balance the resultant force in the reference plane must be zero,

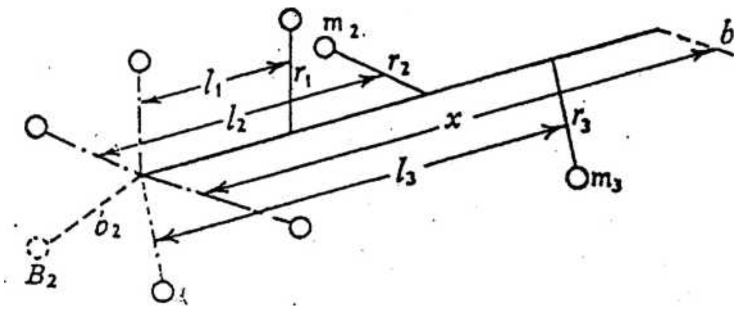


Fig. 3

i.e. $\sum mr = 0$, and the resultant couple in the reference plane must be zero,

i.e. $\sum mrl = 0$

These two conditions, determine the necessary mass-arm products B_1b_1 and B_2b_2 for balance. Thus the closing side of the couple *(mrl)* polygon. Fig. 4, represents the magnitude and direction of the couple required for equilibrium, B_1b_1x, and the closing side of the force *(mr)* polygon, Fig. 5, represents the magnitude and direction of the force, B_2b_2, required in the reference plane for equilibrium

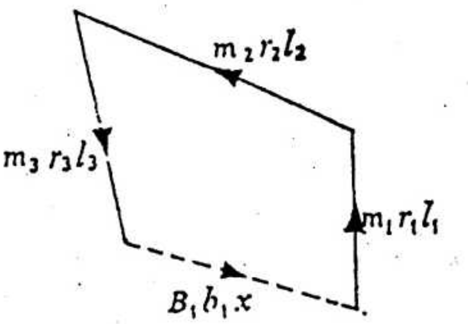


Fig. 4

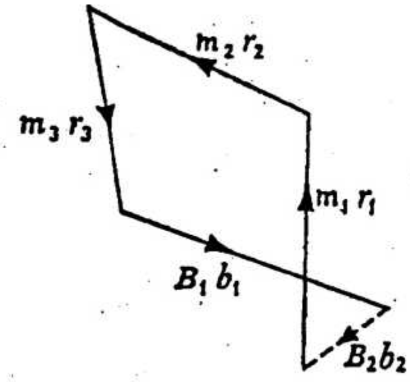


Fig. 5

The reference plane is normally chosen to coincide with the plane of revolution of one of the unknown masses, thus eliminating the couple product by this mass.

In constructing the couple polygon, it is usual to draw the couple vectors in the directions of the respective forces instead of 90° anticlockwise to them, as required by the normal convention for couple vectors. The shape of the polygon is unaffected and it then has sides parallel to those of the force polygon.

When the reference plane divides the planes of revolution of the masses, the vectors for the couples to one side of the plane are drawn radially outwards and those to the other side, being regarded as negative are drawn radially inwards.

PROCEDURE

Since the only possible wide changes may be performed on the longitudinal and angular position of the disk, it is better to choose the rotating, mass wiih a known distance from the center and solving for the longitudinal and angular locations of the masses causing the balancing.

For example if four masses system is performed, two masses are chosen and placed at known angular and longitudinal positions, the other masses position may be found from the force and couple polygons graphically, then performing the results experimentally to verify the system balancing. The same may be done with five masses system by fixing the product mass distance of the third as well as the location of the mass attached to the driven pulley, a solution of complete balancing may be achieved. - ,

Another method, such as the analytical one, may be applied in order to check the results for the unknown parameters.

Experimentally, these results can be performed to verify the system balancing; all of the parameters should be adjusted on the apparatus, masses, and their angles of position in on every disk, their radii, and the disk relative positions from a reference plane. Finaly a clear balancing must happen.

CALCULATIONS AND RESULTS

A table should be constructed in this case to show all of the unknown variables

Plane No.	*m(lb)*	r(in)	*θ(°)*	*l(in)*	*F = m.r*	*M=mrl*
A	0.25	2	262	0	0.5	0
B	0.2	2	110	4.7	0.4	1.88
C	0.4	2	52	11.9	0.8	9.6
D	0.3	2	240	18	0.6	10.8
					$\sum m.r = 0$	$\sum \text{m.r.L} = 0$

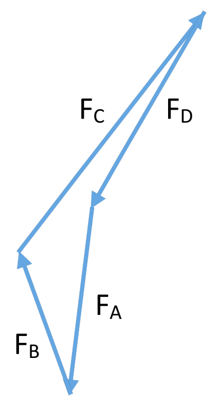
REQUIREMENTS

1- Draw the force polygons clearly on a graph paper.
2- Draw the couple polygons clearly on a graph paper.
3- Table your results.
4- Perform the results experimentally.
5- Discuss and comment.

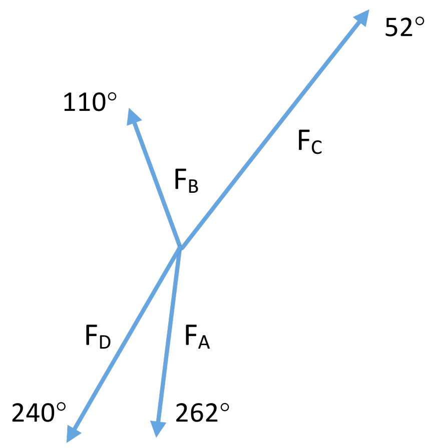
1. Forces Vectors and Polygon

$F_A = 0.25 * 2 = 0.5$ N $\qquad \theta_A = 262°$
$F_B = 0.2 * 2 = 0.4$ N $\qquad \theta_B = 110°$
$F_C = 0.4 * 2 = 0.8$ N $\qquad \theta_C = 52°$
$F_D = 0.3 * 2 = 0.6$ N $\qquad \theta_D = 240°$

Drawing in a scale (2:1) in cm



Force Polygon



Force Vector

2. Couples Vectors and Polygon

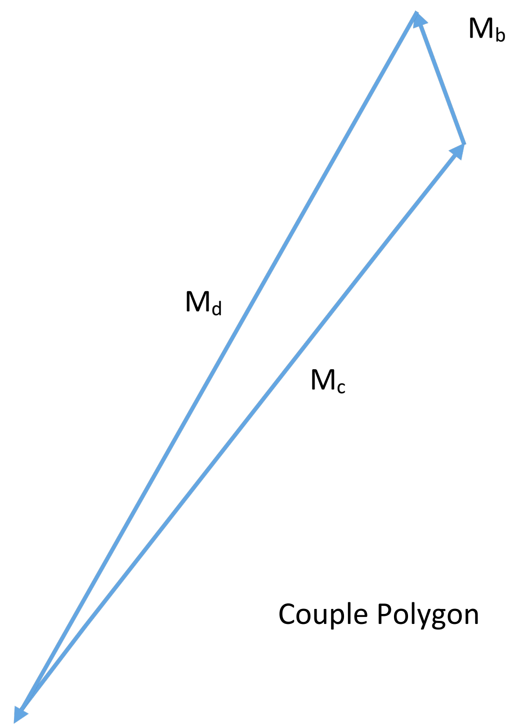
$M = m * r * L$

$M_b = 0.2 * 2 * 4.7 = 1.88$ N.m $\theta = 110°$

$M_c = 0.4 * 2 * 11.9 = 9.6$ N.m $\theta = 52°$

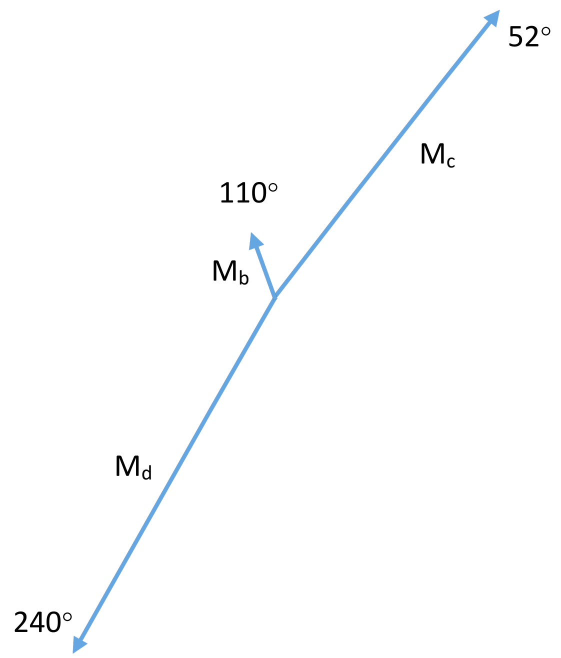
$M_d = 0.3 * 2 * 18 = 10.8$ N.m $\theta = 240°$

Drawing in a scale (1:1) in cm



Couple Polygon

Drawing in a scale (2:1) in cm



Couple Vectors

Dynamic Balancing Experiment

اسم الطالب: عثمان محمود شريف الشعبة: B التاريخ: 2017/11/10

القراءات:

Plane No.	m (lb)	r (in)	θ(°)	L (in)
A	0.25	2	262	0
B	0.2	2	110	4.7
C	0.4	2	52	11.9
D	0.3	2	240	18

ملاحظة

- وحدات القياس بريطانية (Ib) و (in) تبقى كما هي في الحسابات (بدون تحويل) لحاجتنا الى النتيجة النهائية بوحدات بريطانية كذلك.
- عند حساب القوة (F = m . r) و ($a = \omega^2 . r$) ولكون ω (سرعة الدوران) ثابتة خلال التجربة ، فسيتم حساب كافة القوى بدلالة ω^2 . أي ستكون (F = m . r) و (M= m . r . L)

الحسابات:

Plane No.	m (lb)	r(in)	θ(°)	L (in)	F=m.r (N)	M=m. r. L (N.m)
A	0.25	2	262	0	0.5	0
B	0.2	2	110	4.7	0.4	1.88
C	0.4	2	52	11.9	0.8	9.6
D	0.3	2	240	18	0.6	10.8

4. Calculations

$\sum M_A=0$

$m_B\ r_B\ L_B + m_C\ r_C\ L_C + m_D\ r_D\ L_D = 0$

$0.2 \times 2 \times 4.7 \cos(110) + m_C \times 2 \times 11.9 \cos \theta_c + 0.3 \times 2 \times 18 \cos(240) = 0$
$-0.64299 + 2\ m_C \times 11.9 \times \cos \theta_c + (-5.4) = 0$
$2\ m_C \times 11.9 \cos \theta_c = 6.04299$
$11.9\ m_C \cos \theta_c = 3.021495$
$m_C = \frac{0.2539}{\cos \theta c}$ ……. eqn. 1

$0.4 \times 4.7 \sin(110) + m_C \times 2 \times 11.9 \sin \theta_c + 0.6 \times 18 \sin(240) = 0$
$2\ m_C \times 11.9 \sin \theta_c = 7.5864$
$m_C \sin \theta_c = 0.31875$
$m_C = \frac{0.31875}{\sin \theta c}$ ……. eqn. 2

by sub. 2 in 1:

$$\frac{0.31875}{\sin \theta c} = \frac{0.2539}{\cos \theta c}$$

$$\frac{\sin \theta c}{\cos \theta c} = \frac{0.31875}{0.2539}$$

$\tan \theta_c = 1.2354 \longrightarrow \theta_c = \tan^{-1} 1.2354$

$\boxed{\theta_c = 51.46 \approx 52^\circ}$

$\therefore\ m_C = \frac{0.31875}{\sin(52)}$

$m_C = 0.4$ lb

$\sum F_{Ax}=0$

$F_A + F_B + F_C + F_D = 0$

$m_A\, r_A \cos\theta_A + m_B\, r_B \cos\theta_B + m_C\, r_C \cos\theta_C + m_D\, r_D \cos\theta_D = 0$

$2\, m_A \cos\theta_A + 0.2 \times 2 \times \cos(110) + 0.404 \times 2 \times \cos(52) + 0.3 \times 2 \times \cos(240) = 0$

$m_A \cos\theta_A = -0.0303$

$m_A = \frac{-0.0303}{\cos\theta a}$ ……. eqn. 3

$\sum F_{Ay}=0$

$2\, m_A \sin\theta_A + 0.2 \times 2 \times \sin(110) + 0.404 \times 2 \times \sin(52) + 0.3 \times 2 \times \sin(240) = 0$

$m_A \sin\theta_A = -0.24648$

$m_A = \frac{-0.24648}{\sin\theta a}$ ……. eqn. 4

by sub. 3 & 4:

$\frac{-0.24648}{\sin\theta a} = \frac{-0.0303}{\cos\theta a}$

$\frac{\sin\theta a}{\cos\theta a} = \frac{0.24648}{0.0303}$

$\tan\theta_A = 8.13489 \longrightarrow \theta_c = \tan^{-1} 1.2354$

$\boxed{\theta_A = 82.99^\circ} \longrightarrow \theta_A = 82.99 + 180 = 262.99^\circ$

$\therefore\ m_A = \frac{0.24648}{\sin(262.99)} = 0.248 \approx 0.25$ lb

5. Disscussion

An interesting point that has arisen from the analysis is that the human error is the biggest error factor in the results. various methods have been researched which can eliminate this inaccuracy and make the experiment more precise. The most common way to overcome this, and a method often used in industry is a balancing machine. A balancing machine has its bearings connected to sensors (displacement or acceleration type depending on the design of the machine) which detect the "heavy" point, in relation to a datum on the unit, whilst it is being rotated. This increases the sensitivity and, hence, the accuracy of the balance.